Indian Institute of Technology Kanpur

AE451A

Experiments in Aerospace Engineering - III

Experiment No. 11

PERFORMANCE ANALYSIS OF A TWO STAGE AXIAL FAN

Submitted By:

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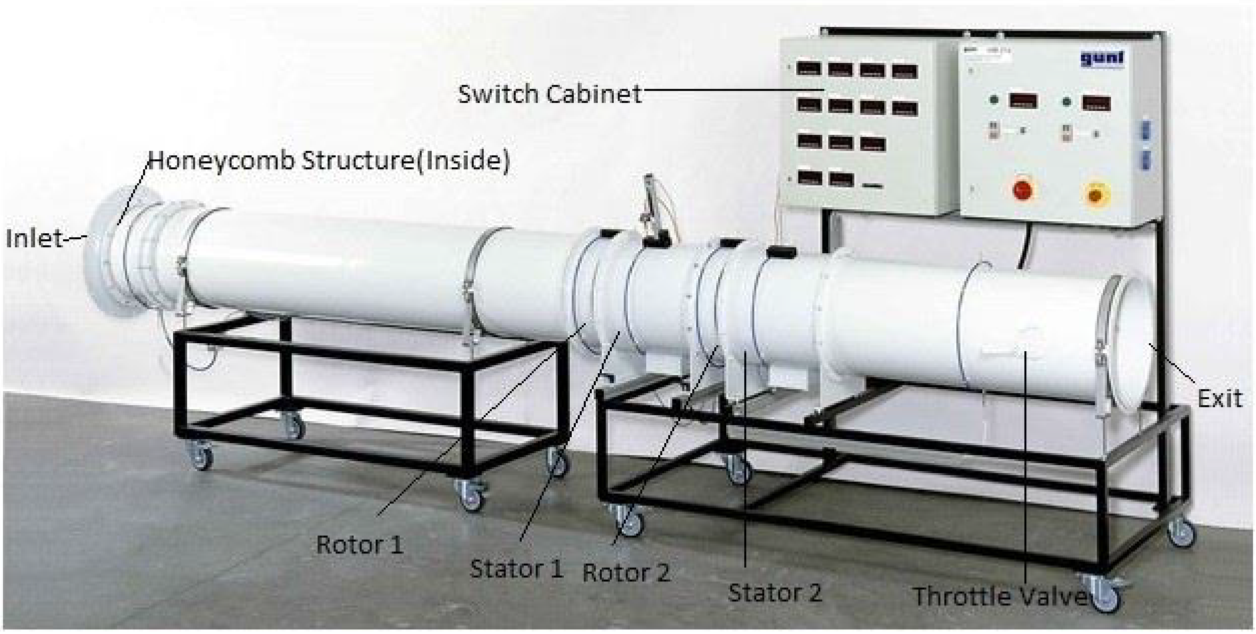
November 8, 2021

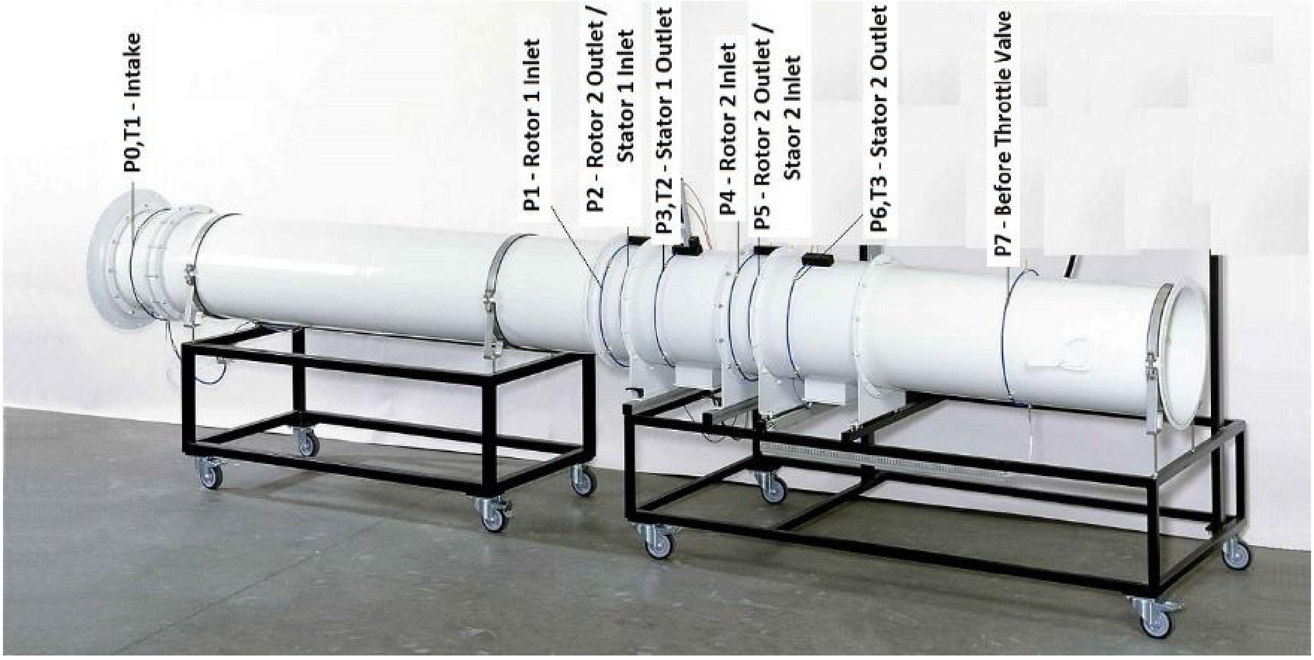
1. Objective

1. To obtain and understand the characteristics of an axial fan.
2. To plot and understand the pressure profiles at different points across an axial fan.

2. Introduction and theory



The axial flow fan test facility consists of two stage axial fan, along with a switch cabinet that will display all relevant operating data, see Figure 1. Each axial rotor has its own motor and speed of each motor can be regulated independently from the switch cabinet using potentiometers. Experiments can be conducted with single rotor also. A movable pipe section component is located directly after the intake pipe in the experimental setup which contains rotor 1. If experiments are to be carried out with only one stage, the movable pipe section can be pushed to the side so that the intake pipe can be screwed directly onto the pipe section containing rotor 2.
A throttle valve is fitted in the pipe section with rotor 2. It can be used to regulate the mass flow and discharge pressure through the compressor. The throttle valve is operated using a lever, which is secured with a wing bolt to prevent unintentional adjustment. See Figure 1 for more details. Pressure measuring connections are fitted at the key points for pressure measurements in the intake pipe, which the user can connect to differential pressure displays in the system (see Figure 2). The holes feed into annular pipes, which are designed to rule out falsification of the measured pressures. The flow rate through the pipe is measured using the static pressure measurement at the inlet. Finally, there are sensors for measuring the air temperature at various locations.



The switch cabinet for the system is divided into two sections. Left-hand section contains digital displays for differential pressures, temperatures, air flow rate, nulling yaw probe (position and angle). It also contains the connection for PC data acquisition. The sensor connections are located on the side of the control cabinet. Right hand side of the cabinet contains emergency stop switch and an ON/OFF button for the fan. The torque and speed of the fan are also shown on the digital display. On the right hand side of the cabinet are two sockets, which can be used to connect additional devices (e.g. a PC).

3. Experimental Procedure

To obtain the compressor characteristics of an axial compressor

1. Set the throttle valve to minimum resistance position, by rotating the lever.
2. Rotate the RPM control switch of both the rotors till the desired RPM is reached.
3. Torques and pressures are measured using various sensors and the readings are displayed in the displays located in the switch cabinet. This corresponds to the first set of readings, note down these readings.
4. Slowly rotate the lever to certain extent to increase the flow resistance (and reduce the mass flow rate), keeping the RPM constant.
5. Note down the torque and pressure readings for this setting as well. Keep repeating this process so that you get 5-8 readings.
6. Then repeat the same experiment at different RPM (at least three different RPMs). The RPMs for each group will be defined by the instructor.
   Following readings should be noted:
    1. Pressure at various points (P1 – P7).
    2. Air flow rate (m3/s) and RPM from the switch cabinet.

3. Temperatures at various points (T1 – T3).
4. Torque in N-m from the switch cabinet.

4. Calculation

Pa = 101325 Pascal

ρ = 1.225 kg/m3

Area = $\frac{\pi * D^2}{4}\ (m^2)$

$$\dot{m} = \dot{Q} * \rho\ (Kg/s)$$

Velocity = $\frac{\dot{Q}}{Area}\ (\frac{m}{s})$

P0 = Pa - $\frac{1}{2} * \rho * V^2\ (Pa)$

N : RPM, T : Torque (N.m)

Power = $\frac{N1*T1+N2*T2}{60}\ Watt$

5. Data analysis

Experimental Data Table

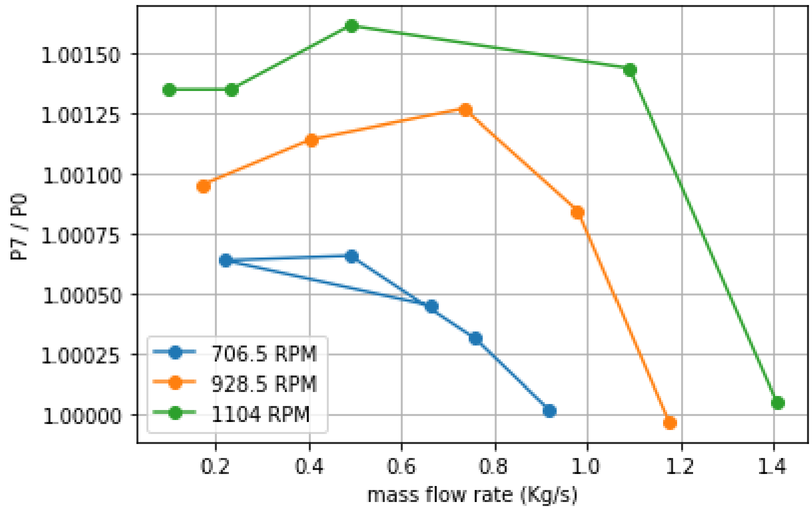
	RPM(N1)	RPM(N2)	Vfr(m^3/s)	Tor1(N*m)	Tor1(N*m).1	P1(Pa)	P2(Pa)	P3(Pa)	P4(Pa)	P5(Pa)	P6(Pa)	P7(Pa)	D (m)
0	708	705	0.75	1.3	1.11	101264	101291	101289	101288	101307	101310	101327	4
1	708	705	0.62	1.3	1.13	101277	101312	101313	101314	101341	101346	101357	4
2	708	705	0.4	1.27	1.14	101294	101337	101335	101342	101380	101379	101392	4
3	708	705	0.18	1.1	1.03	101310	101349	101338	101351	101387	101376	101390	4
4	708	705	0.54	1.31	1.14	101283	101322	101322	101326	101357	101361	101371	4
5	918	939	0.96	1.8	1.48	101220	101266	101260	101259	101291	101353	101322	4
6	918	939	0.8	1.81	1.58	101255	101322	101321	101328	101387	101391	101411	4
7	918	939	0.6	1.71	1.54	101281	101356	101350	101365	101437	101430	101454	4
8	918	939	0.33	1.46	1.37	101301	101368	101350	101372	101436	101415	101441	4
9	918	939	0.14	1.26	1.17	101313	101382	101349	101394	101436	101399	101422	4
10	1102	1106	1.15	2.37	1.82	101177	101247	101239	101236	101279	101286	101330	4
11	1102	1106	0.89	2.34	1.95	101239	101343	101338	101352	101439	101443	101471	4
12	1102	1106	0.4	1.82	1.63	101301	101396	101363	101399	101487	101452	101489	4
13	1102	1106	0.19	1.57	1.4	101346	101410	101362	101426	101462	101430	101462	4
14	1102	1106	0.08	1.62	1.37	101366	101435	101374	101444	101500	101429	101462	4

Calculated Data Table

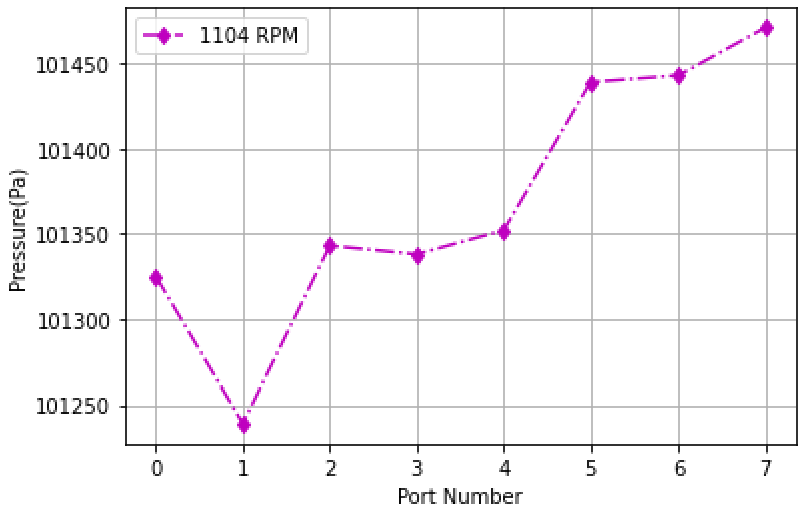
	RPM(N1)	RPM(N2)	Vfr(m^3/s)	P0	P7/P0	dp*Q/Power	mass flow rate (kg/s)	Power (Watt)
0	708	705	0.75	101325	1.00002	0.0529071	0.91875	28.3825
1	708	705	0.62	101325	1.00032	0.693314	0.7595	28.6175
2	708	705	0.4	101325	1.00066	0.944302	0.49	28.381
3	708	705	0.18	101325	1.00064	0.466462	0.2205	25.0825
4	708	705	0.54	101325	1.00045	0.860937	0.6615	28.853
5	918	939	0.96	101325	0.99997	-0.0567348	1.176	50.702
6	918	939	0.8	101325	1.00085	1.31251	0.98	52.42
7	918	939	0.6	101325	1.00127	1.53989	0.735	50.264
8	918	939	0.33	101325	1.00114	0.874405	0.40425	43.7785
9	918	939	0.14	101325	1.00096	0.361281	0.1715	37.5885
10	1102	1106	1.15	101325	1.00005	0.0746766	1.40875	77.0777
11	1102	1106	0.89	101325	1.00144	1.64645	1.09025	78.923
12	1102	1106	0.4	101325	1.00162	1.0335	0.49	63.4737
13	1102	1106	0.19	101325	1.00135	0.476371	0.23275	54.6423
14	1102	1106	0.08	101325	1.00135	0.199245	0.098	55.0077

6. Results

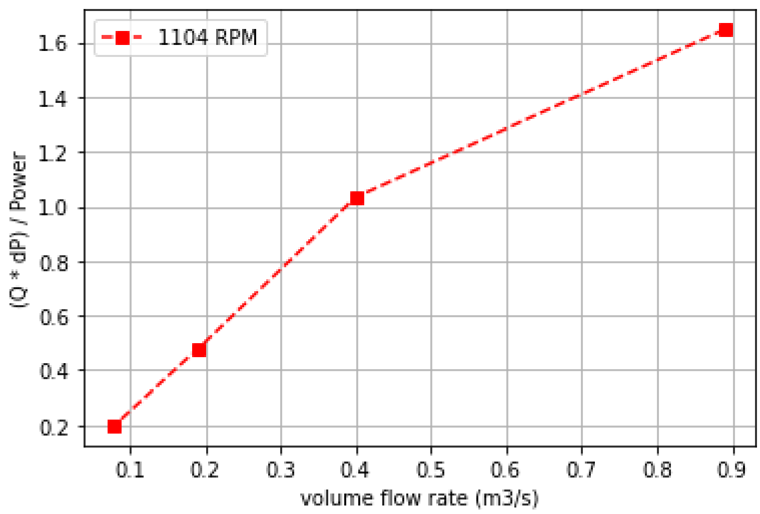
1. overall pressure ratio (P7/P0) vs. mass flow rate ($\dot{m}$) for the three different RPM (N) settings



2. Pressure profile across different points at 1104 RPM and $\dot{Q} = 0.89$



3. At 1104 RPM, $\frac{Q*\delta P}{Power}$ vs Volume flow rate ($\dot{Q}$)



7. Discussion

1. Ratio of P7 and P0 are nearly 1 and decrease with mass flow rate is increasing
2. Across the flow, pressure increase from inlet to exit of the chamber.
3. Ratio Q*dP/Power increases with Volume flow rate increase.

8. Precautions

1. Prior to measurement, all the pressure sensors must be set to “0”. To do this, press the RST button on the display (only for pressure not for temperature).
2. Vary RPM in a controlled manner. Never exceed 2100 RPM (75% of the rated RPM, i.e. 2800 RPM).
3. In case of an emergency, stop the setup by pressing emergency stop switch located on the right side of the switch cabinet.
4. Ensure that all wires are properly insulted. If there is any open length of wire, wrap insulation tape around it or replace the wire.
5. If both fans are to be operated at the same time, they must be switched ON at the same time. Once one fan is already being operated at a higher speed, second fan cannot subsequently be switched ON.
6. Do not take measurements continuously. Give a minimum time gap of 60 seconds between measurements after changing the throttle valve position or RPM.

9. References

Lab 11 Data anlysis Jupyter Notebook